Chapter-4

Diurnal and Seasonal Variations in the Occurrence of Pc4 Pulsations
4.1 Hourly Occurrence of Pc4 (HRO): -

Determining the hourly occurrence of ULF waves and their seasonal variation is important for quantifying their propagation and generation mechanism properties. In this regard, the results of the analysis of diurnal variation in the occurrence of geomagnetic Pc4 pulsations during the whole year 2005 recorded at three stations situated at very low latitudes in India are reported in this chapter. Occurrence periods of events in each day were observed and consequently the monthly analysis of occurrence period corresponding to each hour bin was carried out [Ansari et al., 2009(a)].

4.1.1 HRO for January 2005: -

The hourly occurrence (HRO) of Pc4 events for all the three stations (Nagpur, Hanle and Pondicherry) for the month of January 2005 is shown in Fig. 4.1 [Ansari et al., 2009(a)]. The time is expressed in UT on X-axis and the total duration of events for corresponding hour for the whole month is depicted on Y-axis. The results for Y-components are also plotted for comparative studies. It is evident from the graph that events occurred in all the hours of the day while major occurrence was seen between 14 hr UT to 21 hr UT at all the three stations. The main peak was found in 17-18 hr UT interval at all the three stations with maxima decreasing in the station order Nagpur, Hanle and Pondicherry. At Nagpur the main 17-18 hr UT peak was of duration 211 min., with a secondary peak at 15-16 hr UT of duration 188 min. Correspondingly in Y-component of Nagpur, the main peak was found at 17-18 hr UT with duration 180 min., and the secondary peaks at 15-16 hr UT and 18-19 hr UT were of 159 min. and 158 min. durations respectively.

The main 17-18 hr UT peak at Hanle was of duration 194 min. The secondary peaks at Hanle were at 15-16 hr UT and 18-19 hr UT of duration 192 min. each. Correspondingly in Y-component of Hanle, the main peak
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was found in 17-18 hr UT with duration 184 min., and the secondary peaks at 15-16 hr UT and 18-19 hr UT were of 167 min. and 168 min. durations respectively. At Pondicherry station, the main 17-18 hr UT peak was of duration 187 min. with secondary peak at 18-19 hr UT of duration 180 min. The secondary peaks at 15-16 hr UT and 14-15 hr UT were of duration 168 min. each. The plots of Y-component show nearly same pattern with less amplitude.

The data of 20 Jan.-2005 for Nagpur and 16 Jan. for Hanle was not available but it did not affect plots significantly since data of these dates had very small durations belonging to midday hours (06-14 hr UT).

4.1.2 HRO for February 2005: -

Fig.4.2 shows the hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of February 2005. Occurrence of Pc4 events was showing nearly same pattern at all the stations. It can be described in two groups. The first group was observed in between 02 hr UT to 06 hr UT while the second was seen in between 09 hr to 23 hr UT. At all the three stations the majority of events was seen between 10 hr UT to 20 hr UT with the main peak at 17-18 hr UT interval with maxima decreasing in the station order Nagpur, Hanle and Pondicherry. At Nagpur the main 17-18 hr UT peak was of duration 205 min. with secondary peak at 15-16 hr UT of duration 191 min. The plots of Y-components also provided the same pattern with less amplitude. The maximum peak was found at 17-18 hr UT with duration 191 min. and the secondary peak was at 15-16 hr UT of 173 min. duration.

At Hanle, the main 17-18 hr UT peak was of duration 199 min. with a secondary peak at 15-16 hr UT of duration 198 min. Correspondingly in Y-component of Hanle, the main peak was also at 17-18 hr UT with duration 191 min. with secondary peak at 15-16 hr UT of duration 188 min.
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At Pondicherry station, the main 17-18 hr UT peak was of duration 191 min. with secondary peak at 15-16 hr UT of duration 181 min. The plot of Y-component have also nearly same pattern with less amplitude. The data of 24 Feb.-2005 for Pondicherry was not available. That is the reason due to which the 20-21 hr UT peak in the plot of Pondicherry station is small in comparison to other stations.

4.1.3 HRO for March 2005: -

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of March 2005 is shown in Fig. 4.3. It is clear from the figure that events occurred in all the hours of the day and showed nearly same pattern at all the three stations. The main peak was found in the 17-18 hr UT interval at all the three stations with maxima decreasing in the station order Hanle, Nagpur and Pondicherry. The major occurrence was in between 15 hr to 22 hr UT at all the three stations. At Nagpur the main 17-18 hr UT peak was of duration 311 min. with secondary peaks at 08-09 hr and 09-10 hr UT of duration 238 min. and 224 min. respectively.

The main 17-18 hr UT peak at Hanle was of duration 314 min. The secondary peaks at 08-09 hr and 09-10 hr UT were found having durations 239 min. and 236 min. respectively. At Pondicherry, the main 17-18 hr UT peak was found to be of duration 308 min. with secondary peaks at 08-09 hr and 09-10 hr UT having durations 253 min. and 239 min. respectively. The plots of Y-component at all the stations have also nearly similar pattern with decrease in the height of the peaks.

4.1.4 HRO for April 2005: -

Fig. 4.4 shows the hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of April 2005.
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Fig. 4.1: Diurnal variation in Pc4 occurrence at all three stations in January 2005.

Fig. 4.2: Diurnal variation in Pc4 occurrence at all three stations in February 2005.
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Fig. 4.3: Diurnal variation in Pc4 occurrence at all three stations in March 2005.

Fig. 4.4: Diurnal variation in Pc4 occurrence at all three stations in April 2005.
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Fig. 4.5: Diurnal variation in Pc4 occurrence at all three stations in May 2005.

Fig. 4.6: Diurnal variation in Pc4 occurrence at all three stations in June 2005.
Occurrence of Pc4 events was showing nearly same pattern at all the three stations and the majority of events were seen between 14 hr to 21 hr UT with the main peak at 15-16 hr UT interval.

At Nagpur the main 15-16 hr UT peak was found to have duration of 344 min. with secondary peaks at 16-17 hr and 20-21 hr UT of durations 209 min. and 215 min. respectively. Correspondingly in the Y-component of Nagpur, the main peak was found to be in the 15-16 hr UT with duration of 327 min. while the secondary peak at 14-15 hr UT was found to have more duration than the other peaks occurring at 16-17 hr and 20-21 hr UT.

The main 15-16 hr UT peak at Hanle was found with duration 347 min. The secondary peaks at Hanle were also observed at 16-17 hr UT and 20-21 hr UT with durations 225 min. and 216 min. respectively. The plot of Y-component also showed nearly same pattern with less amplitude. At Pondicherry also, the main 15-16 hr UT peak was found having duration 344 min. with secondary peaks at 16-17 hr and 20-21 hr UT having durations 214 min. and 221 min. respectively. The plot of Y-component also showed nearly same pattern with less amplitude except that the secondary peak at 14-15 hr UT was found to be somewhat larger than other peaks at 16-17 hr and 20-21 hr UT.

**4.1.5 HRO for May 2005:** -

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of May 2005 is shown in Fig. 4.5. It is clear from the figure that events occurred during all the hours of the day at all the stations. It can be described by two groups. The first group lies in between 04 hr to 09 hr UT and the second one in between 14 hr to 20 hr UT time interval. It was found that the main peak in the month of May-05 was in between 06-07 hr UT interval at all the three stations. The secondary peaks were found in 15-20 hr UT interval.
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At Nagpur the main 06-07 hr UT peak was of duration 272 min. with secondary peaks at 05-06 hr, 17-18 hr and 18-19 hr UT having durations 216 min., 170 min. and 174 min. respectively. At Hanle, the main 06-07 hr UT peak was found to be of duration 343 min. and the secondary peaks at 05-06 hr, 17-18 hr and 18-19 hr UT were found having durations 276 min., 214 min. and 208 min. respectively. At Pondicherry, the main 06-07 hr UT peak was found having duration 340 min. and the secondary peaks at 05-06 hr, 17-18 hr and 18-19 hr UT were found having durations 279 min., 205 min. and 204 min. respectively. The plots of Y-components of all the three stations showed nearly similar pattern with X-component but the amplitudes of the peaks were found to be relatively smaller.

The data for 21st and 27th-31st of May-2005 for Nagpur were not available. That is why the main 06-07 hr UT peak and the secondary peaks were found with less amplitude at Nagpur station.

4.1.6 HRO for June 2005: -

Fig.4.6 shows the hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of June 2005. Occurrence of Pc4 events was showing nearly same pattern at all the three stations and the majority of events were seen between 17 hr to 22 hr UT. At Nagpur station the main peak was found to be at 18-19 hr UT with duration 190 min., with secondary peak at 19-20 hr UT of duration 165 min. Correspondingly in the Y-component of Nagpur, the main 18-19 hr UT peak was found having duration 166 min. and the secondary peaks at 17-18 hr UT and 19-20 hr UT were of 100 min. and 90 min. durations respectively.

At Hanle station the main peak was found at 17-18 hr UT having duration 163 min. with secondary peaks at 18-19 hr and 19-20 hr UT having durations 154 min. and 145 min. respectively. Correspondingly in
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Y-component of Hanle, the main 17-18 hr UT peak was found having duration 152 min. and secondary peaks at 18-19 hr and 19-20 hr UT of duration 135 min. and 115 min. respectively. At Pondicherry, the maximum occurrence was found between 18-19 hr UT with duration 248 min., with secondary peaks at 17-18 hr and 19-20 hr UT with durations 203 min. and 178 min. respectively. Occurrence of Y-component was nearly similar to that of X-component but the amplitudes were less. The main 18-19 hr UT peak was having duration 193 min. and the secondary peaks at 17-18 hr UT and 19-20 hr UT were found to have durations of 159 min. and 118 min. respectively.

The data of 09\textsuperscript{th} and 23\textsuperscript{rd}-30\textsuperscript{th} of June-2005 for Nagpur were not available and that was the reason due to which the 14-15 hr and 16-17 hr peaks were absent in the Nagpur plot and also the occurrence durations between 02-10 hr UT interval was very less. The data of 10\textsuperscript{th}-12\textsuperscript{th} June-05 for Hanle were not available. The events in these days were mainly occurred in between 17-22 hr UT interval and that is why the maximum occurrence peak at Hanle was of less duration.

4.1.7 HRO for July 2005:

Fig.4.7 shows the hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of July 2005. Occurrence of Pc4 events was showing nearly same pattern at all the stations. It can be classified in two groups. The first group was seen between 03 hr to 07 hr UT but the majority of events were lying in between 16-24 hr UT. The maximum occurrence peak at all the three stations was found to be at 18-19 hr UT interval with maxima decreasing in the station order Hanle, Nagpur and Pondicherry. The plots of Y-components of all the three stations showed nearly similar pattern as X-component but the amplitudes of the peaks were found to be smaller.
At Nagpur, the main 18-19 hr UT peak was found to be of duration 181 min. The secondary peaks were found at 17-18 hr and 21-22 hr UT having durations 166 min. and 168 min. respectively. The main 18-19 hr UT peak found at Hanle was of duration 182 min. The secondary peaks were found at 17-18 hr and 22-23 hr UT having durations 167 min. and 158 min. respectively. At Pondicherry, the main 18-19 hr UT peak was having duration 178 min. with secondary peaks at 17-18 hr UT and 21-22 hr UT with durations 157 min. and 168 min. respectively.

The data of 20th and 27th July-2005 for Hanle were not available. That was the reason why the occurrence peaks at 12-13 hr and 13-14 hr UT were absent in the plot for Hanle and the secondary peak at 21-22 hr UT was found to be smaller than the 22-23 hr UT secondary peak.

4.1.8 HRO for August 2005:

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of August 2005 is shown in Fig. 4.8. It is clear from the figure that events occurred in all the hours of the day at Nagpur and Pondicherry stations and the occurrence behavior was nearly similar. At Hanle, data for only 5 days in August-05 were available and that is why the behavior found at Hanle was totally different. The plots of Y-components of all the three stations showed nearly similar pattern as that of X-component but the amplitudes of the peaks were found to be smaller.

At Nagpur, the majority of events were lying in between 04-12 hr and 16-23 hr UT intervals. The clear major peak was found at 17-18 hr UT having duration 393 min. The secondary peaks were found at 09-10 hr and 21-22 hr UT having durations 234 min. and 254 min. respectively. In the available data of 5-days at Hanle, the maximum occurrence was found at 17-18 hr UT in both X and Y components having durations 119 min. and 120 min.
respectively. At Pondicherry, the clear major peak was found at 17-18 hr UT having duration 390 min. The secondary peaks were found at 09-10 hr and 21-22 hr UT having durations 254 min. and 258 min. respectively.

4.1.9 HRO for September 2005: -

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of September 2005 is shown in Fig. 4.9. During this month, the data of very few days for Hanle and Nagpur were available. That is why the results of this plot are not much reliable and are not described in detail.

4.1.10 HRO for October 2005: -

Fig. 4.10 shows the hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of October 2005. It is clear from the figure that events occurred in all the hours of the day at Nagpur and Pondicherry but the majority of occurrence was seen between 14-21 hr UT. At Hanle the data of only 09 days in October-05 were available. Consequently the behavior found at Hanle was different in comparison to the other two stations. The plots of Y-components of all the three stations showed nearly similar pattern as X-component but the amplitudes of the peaks were found to be less.

At Nagpur, there was maximum occurrence found at 18-19 hr UT having duration 360 min. with nearly same duration peak at 19-20 hr UT having duration 344 min. There was also a secondary peak at 17-18 hr UT having duration 286 min. In the available data of 09 days for Hanle, the maximum occurrence was found to be at 18-19 hr UT having duration 149 min. with secondary peaks at 16-17 hr and 19-20 hr UT with durations 119 min. and 97 min. respectively. At Pondicherry, there was a maximum occurrence found at 19-20 hr UT having duration 347 min. with nearly same amplitude peak at 18-19 hr UT having duration 340 min. There was also a secondary peak found at 17-18 hr UT having duration 286 min.
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Fig. 4.7: Diurnal variation in Pc4 occurrence at all three stations in July 2005.

Fig. 4.8: Diurnal variation in Pc4 occurrence at all three stations in August 2005.
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Fig. 4.9: Diurnal variation in Pc4 occurrence at all three stations in September 2005.

Fig. 4.10: Diurnal variation in Pc4 occurrence at all three stations in October 2005.
4.1.11 **HRO for November 2005:**

Fig. 4.11 shows the hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of November 2005. Occurrence of Pc4 events was showing nearly similar pattern at all the three stations. At all the three stations events occurred in all the hours of the day but the majority of events were found between 15 hr to 24 hr UT. The maximum occurrence peak was found to be at 18-19 hr UT interval at all the three stations.

At Nagpur the main 18-19 hr UT peak was found having duration 321 min. with secondary peak at 17-18 hr UT with duration 277 min. Correspondingly in the Y-component of Nagpur, the main 18-19 hr UT peak was found to be having duration 280 min. and the secondary peak at 17-18 hr UT was found with 258 min. duration. At Hanle, the main 18-19 hr UT peak was found having duration 298 min. with the secondary peak at 17-18 hr UT with duration 229 min. Correspondingly in the Y-component of Hanle, the main 18-19 hr UT peak was found with duration 291 min. and the secondary peak at 17-18 hr UT was found having 222 min. duration. At Pondicherry, the maximum occurrence found at 18-19 hr UT was with duration 307 min. The secondary peak at 17-18 hr UT was with duration 272 min. Occurrence of Y-component was nearly similar as X-component but the amplitudes were smaller. The main 18-19 hr UT peak was found with duration 290 min. and the secondary peak at 17-18 hr UT was found having 248 min. duration.

The data of 17th and 18th of Nov.-05 for Hanle were not available. The events in these days were mainly in between 17-21 hr UT interval and that is why the maximum occurrence peak and the secondary peak at 18-19 hr and 17-18 hr UT at Hanle were of less durations in comparison to the other stations.
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4.1.12 HRO for December 2005:

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the month of December 2005 is shown in Fig. 4.12. It can be seen from the plot that occurrence of Pc4 events was showing nearly similar pattern at all the three stations. At all the three stations events occurred in all the hours of the day but the majority of events were found between 15 hr to 23 hr UT. The maximum occurrence peak was found to be in the 18-19 hr UT interval at all the three stations. The plots of Y-components of all the three stations showed nearly similar pattern as X-component but the amplitudes of the peaks were found to be smaller.

At Nagpur the main 18-19 hr UT peak was found having duration 403 min. with secondary peak at 19-20 hr UT of duration 335 min. At Hanle, the main 18-19 hr UT peak was found having duration 402 min. with the secondary peak at 19-20 hr UT of duration 346 min. At Pondicherry, the maximum occurrence found at 18-19 hr UT was having duration 457 min. The secondary peak at 19-20 hr UT was of duration 408 min.

The data of 21st and 28th-31st Dec.-05 for Nagpur were not available. That is why the occurrence durations in between 01-10 hr UT and the secondary peak were found with smaller durations at Nagpur. The data for 1st and 27th Dec.-05 for Hanle were also not available.

4.1.13 HRO for the Total Year 2005:

The variation of total hourly occurrence of Pc4 events for all the three stations for the whole year 2005 is plotted in Fig. 4.13[Ansari et al., 2009(a)]. It is clear from the plot that the occurrence was found in all the hours of the day with the major occurrence being observed between 15 hr to 22 hr UT at all the three stations. The occurrence pattern was nearly similar for all stations and the maximum occurrence was at 17-18 hr UT.
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Fig. 4.11 Diurnal variation in Pc4 occurrence at all three stations in November 2005.

Fig. 4.12 Diurnal variation in Pc4 occurrence at all three stations in December 2005.
with a succeeding secondary peak at 18-19 hr UT. The Maxima was found decreasing in the station order Pondicherry, Nagpur and Hanle as is evident from the plot of the total year. The variation in Y component occurrence was also nearly similar with less power observed. For Hanle, the duration in Pc4 occurrence was found to be less dominant in comparison to other stations. The main reason of this was the unavailability of data in most of the days in August, September and October 2005 for this station.
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4.2 Seasonal Variations in Pc4 Occurrence:

The seasonal variations of diurnal occurrence of these very low latitude Pc4 waves were also studied and are described in this section. The hourly occurrence (HRO) of Pc4 events for each season, i.e., for winter (December, January and February), spring (March, April and May), summer (June, July and August) and autumn (September, October and November) is analyzed for the year 2005 and reported below [Ansari et al., 2009(a)].

4.2.1 HRO for Winter:

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the winter season (December, January and February) is shown in Fig. 4.14 [Ansari et al., 2009(a)]. It can be seen from plot that the occurrence of Pc4 events is showing nearly similar pattern at all the three stations. Events occurred in all the hours of the day but the majority of events were found to be occurring between 15 hr to 20 hr UT. The maximum occurrence peak was found in between 18-19 hr UT interval at all the three stations. The plots of Y-components for all the three stations showed nearly similar pattern as X-component but the amplitudes of the peaks were found to be smaller.

At Nagpur the main 18-19 hr UT peak was found having duration 688 min. with secondary peak at 19-20 hr UT of duration 606 min. At Hanle, the main 18-19 hr UT peak was found with duration 708 min., with secondary peak at 19-20 hr UT having duration 633 min. At Pondicherry, the maximum occurrence found at 18-19 hr UT was of duration 751 min. The secondary peak at 19-20 hr UT was found having duration 607 min.

The data of 20th Jan.-05 for Nagpur and 16th Jan. for Hanle were not available but it did not affect plots significantly since data of these dates had very small durations in the 06-14 hr UT interval.
4.2.2 HRO for Spring:

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the spring season (March, April and May) is shown in Fig. 4.15 [Ansari et al., 2009(a)]. Occurrence of events can be classified in two groups. The first group was seen between 05 hr to 11 hr UT but the majority of events were lying in between 14-21 hr UT. The maximum occurrence peak at all the three stations was found to be at 17-18 hr UT interval.

The main 17-18 hr UT peak found at Nagpur was having duration 680 min. while the secondary peak found at 15-16 hr UT was of duration 558 min. Correspondingly in Y-component of Nagpur, 17-18 hr UT peak was observed with duration 606 min. and the secondary peak found at 15-16 hr UT was of duration 506 min. At Hanle, the main 17-18 hr UT peak was found with duration 737 min. and the secondary peak found at 15-16 hr UT was of duration 608 min. Correspondingly in the Y-component of Hanle, 17-18 hr UT main peak and the secondary peak at 15-16 hr UT were found with durations 689 min. and 547 min. respectively. At Pondicherry, the maximum occurrence found at 17-18 hr UT was having duration 712 min. The secondary peak at 15-16 hr UT had duration 559 min. Occurrence of Y-component was nearly similar to X-component but the observed power was less. The main 17-18 hr UT peak was found with duration 634 min. and the secondary peak at 15-16 hr UT was found having 502 min. duration.

4.2.3 HRO for Summer:

Fig. 4.16 [Ansari et al., 2009(a)] shows the hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the summer season (June, July and August). It is clear from the figure that the occurrence behavior at Nagpur and Pondicherry was nearly similar but the
behavior found at Hanle was different in comparison to the other two stations. The cause of this was the unavailability of data in most of the days in August for Hanle. The majority of events were lying in between 17 hr to 22 hr UT at all the three stations. The maximum occurrence peak at all the three stations was found to be in the 17-18 hr UT interval. The plots of Y-components of all the three stations showed nearly similar pattern as the X-component but less power was observed during most of the time and hence the amplitudes (duration values) of the peaks were found to be smaller.

The main 17-18 hr UT peak found at Nagpur was having duration 693 min. with secondary peak at 18-19 hr UT of duration 531 min. At Hanle, the main 17-18 hr UT peak was found with duration 449 min. with secondary peak at 18-19 hr UT having duration 366 min. At Pondicherry, the maximum occurrence found at 17-18 hr UT was with duration 750 min. The secondary peak at 18-19 hr UT was found having duration 585 min.

4.2.4 HRO for Autumn: -

The hourly occurrence of Pc4 events (both X and Y components) for all the three stations for the autumn season (September, October and November) is shown in Fig. 4.17 [Ansari et al., 2009(a)]. It is clear from the figure that the occurrence behavior at Nagpur and Pondicherry was nearly similar but the behavior found at Hanle was different as compared to the other two stations. The cause of this was the unavailability of data in most of the days in September and October for Hanle. The majority of events were lying in between 15 hr to 21 hr UT at all the three stations. The maximum occurrence peak at all the three stations was found to be in the 18-19 hr UT interval. The plots of the Y-components of all the three stations showed nearly similar pattern as those of the X-component but less power was observed during most of the time and hence the amplitudes (duration values) of the peaks were found to be smaller.
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The main 18-19 hr UT peak found at Nagpur was observed having duration 737 min. with the secondary peak at 17-18 hr UT having duration 604 min. At Hanle, data for only 4 days in September and for 9 days in October were available. In the available data the main 18-19 hr UT peak was found having duration 447 min. with secondary peaks at 16-17 hr and 17-18 hr UT having durations 314 min. and 309 min. respectively. At Pondicherry, the maximum occurrence found at 18-19 hr UT was observed having duration 723 min. The secondary peak at 17-18 hr UT was found to have duration 628 min.

Fig. 4.14: Diurnal variation in Pc4 occurrence at all three stations in winter season.  
[After Ansari et al., 2009(a)]
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Fig. 4.15: Diurnal variation in Pc4 occurrence at all three stations in spring season. [After Ansari et al., 2009(a)]

Fig. 4.16: Diurnal variation in Pc4 occurrence at all three stations in summer season. [After Ansari et al., 2009(a)]
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Fig. 4.17: Diurnal variation in Pc4 occurrence at all three stations in autumn season. [After Ansari et al., 2009(a)]